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(54) CRANE ASSEMLY WITH COLLISION SAFEGUARD

(71) We, FRIED. KRUPP GESELLSCHAFT MIT BESCHRÄNKTER HAFTUNG, of 103 Altendorfer Strasse, D-43 Essen, Federal Republic of Germany, a German Body Corporate,

do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

It is known to safeguard from collision cranes which run on the same rails by devices, which sense the distance between the cranes and which operate photoelectrically, electromechanically or on the echo-sounding principle. The present invention provides for avoidance of the risk of collision in crane assemblies, e.g. in shipyards, in which cranes of different types, e.g. gantry cranes, hammer head cranes and rotary cranes, run on different rails with the possibility of one crane passing by or under another crane.

The invention accordingly provides a crane assembly comprising at least two cranes mounted to travel on rails so that they can pass each other or so that one crane can pass under another, transmitters on the cranes for emitting data representing the instantaneous positions of the cranes and of parts of the cranes and/or of loads carried by the cranes which are subject to danger of collision upon approach of the cranes towards one another, and a computer having a receiver for receiving the transmitted data, the computer being programmed to form imaginary envelopes from the received data which surround crane parts and/or loads subject to danger of collision and emitting a warning signal when two envelopes become dangerously close to one another.

The invention affords the advantage of avoiding accidents which could occur, for example, from the jib of a rotary crane striking a support or girder of a gantry crane when passing by or under the gantry crane. The personnel are thus safeguarded against accident and the economy of operation of the cranes is improved. Not only can insurance premiums be reduced, but loss of working time and penalties for failure to fulfil a contract, which can be very heavy in shipbuilding, are avoided. Further the collision safeguarding equipment can easily be fitted to existing cranes.

Embodiments of the invention are illustrated in the accompanying drawings, in which:—

Figure 1 is a diagrammatic perspective view of a crane assembly,

Figure 2 is a corresponding plan view showing, in addition, a gantry crane,

Figure 3 is an end view of a crane assembly constituted by a gantry crane and a rotary crane looking in the direction of travel,

Figure 4 is a corresponding plan view,

Figure 5 is a view similar to Figure 3 showing the same crane assembly in a different condition,

Figure 6 is a corresponding plan view,

Figure 7 is an end view of another crane assembly constituted by a gantry crane and a rotary crane looking in the direction of travel,

Figure 8 is a section on the line VIII—VIII in Figure 7,

Figure 9 shows another crane assembly in a shipyard looking in the direction of travel,

Figure 10 is the corresponding plan view,

Figure 11 is an end view of part of the same crane assembly in a different condition looking in the direction of travel,

Figures 12 and 13 are respectively sections on the lines XII—XII and XIII—XIII in Figure 11 in two different positions of the cranes,

Figure 14 shows another part of the same crane assembly in a still different condition looking in the direction of travel,

Figure 15 is the corresponding plan view and

Figure 16 is a block circuit diagram.

Figures 1 and 2 show two rails 1 in a shipyard supporting a gantry crane 2 and, in the case of Figure 2, a second gantry crane 3. Each gantry crane consists of a support 4 carrying a girder 5, a hinged support 6 and a chassis 7. Between the rails 1 are two rails 8 constituting a track of narrower gauge and supporting a rotary crane 9 having a luffing

jib 10. The undercarriage 11 of the rotary crane supports a superstructure 12 rotatable about a vertical axis and carrying luffing gear 13.

Alongside and parallel to the track formed by the rails 1 are two rails 14 supporting a hammer head crane 15, including a column 18 which is rotatable about a vertical axis in a superstructure 16 on its undercarriage 17 and carries a jib 19. A crab 20 supporting a load 21 is mounted to travel on the jib 19.

Under certain circumstances the rotary crane 9 is required to travel through the gantry of the gantry crane 2 or 3, with which it would collide if the jib 10 were positioned transversely to the direction of travel as shown in Figures 1 and 2. The superstructure 12 must therefore be rotated through approximately 90° from the positions shown in Figures 1 and 2 to render the passage possible. Also the jib 10 must be lowered sufficiently to avoid collision with the girders 5 of the gantry cranes.

Under certain other circumstances the hammer head crane 15 is required to travel past the gantry cranes 2, 3. This is not possible with the jib 19 in the position shown in Figures 1 and 2 because the jib and possibly the load 21 suspended from the crab 20 would collide with the supports 4, 6 and the girders 5 of the gantry cranes. The jib 19 must therefore be rotated through approximately 90° from the position shown in Figures 1 and 2. Also, collision with the jib 10 of the rotary crane and with the load 22 suspended from it must be prevented by swivelling the superstructure 12 of the rotary crane.

To avoid collision between the cranes 2, 3, 9, 15 the following apparatus is provided.

This apparatus includes a computer 23 disposed at a fixed position near the crane assembly. As shown in Figure 16, the computer 23 is connected by a connection 25 to a receiver 24. Associated with this receiver are transmitters 26 which are mounted on the aforesaid cranes and receive from pick-ups 27 data which are representative of the instantaneous position of the associated crane or crane part. These data correspond with the travel and rotary movements of the driving mechanisms of the associated cranes.

Thus from the chassis of the two gantry cranes 2, 3 data are supplied to the associated pick-ups 27 which correspond to the instantaneous positions of travel of these cranes. These data are transmitted by the transmitters 26 of these cranes to the receiver 24. From these data the computer 23 determines the instantaneous positions of the gantry cranes on the rails 1.

The rotary crane 3 has three transmitters 26 and three pick ups 27, the latter of which pick up from the chassis, the luffing gear and the rotating mechanism, the data representative of the travel of the undercarriage 11, the luffing movement of the jib 10 and the rotational movement of the superstructure 12. These data are also sent by the transmitters of the rotary crane to the receiver 23. The computer thus receives data representing the instantaneous position of the rotary crane 9 on the rails 8 and the instantaneous position of adjustment of the jib 10.

The hammer headed crane has three pick ups 27, which pick up from the crane chassis, the rotating mechanism and the crab chassis data representative of the travel of the undercarriage 17, the angular position of the jib 19 and the travel of the crab 20. These data are sent by the transmitters 26 to the receiver 24 of the computer 23, which thus receives data representing the instantaneous positions of the hammer headed crane 15 on the rails 14, the jib 19 and the crab 20.

The computer 23 forms from the received data imaginary envelopes which surround the cranes at a certain spacing. These envelopes are shown in faint lines in Figure 1 and in Figure 2 by chain-dotted lines surrounding the cranes. The envelopes do not follow all projections and recesses in the outline of the cranes but, for simplicity, are prismatic. Thus the gantry cranes 2 and 3 are surrounded by rectangular envelopes 28, 29 which extend from the highest points of the cranes almost to the ground.

The rotary crane 9 is surrounded by a prismatic envelope 30 which includes a tapering upwardly extending portion surrounding the jib 10. When the jib 10 is luffed upwardly the base of the prismatic envelope 30 is shortened and the tapering portion is extended upwardly. When the jib 10 is luffed downwardly the base of the envelope 30 is lengthened and the peak of the tapering portion is lowered. When the superstructure 12 is rotated about the vertical axis in relation to the undercarriage 11, the envelope takes the form indicated at 30^1 in Figure 2.

The hammer head crane 15 is surrounded by an envelope 31, shown in Figure 1 as having the form of a parallelopiped which surrounds the entire hammer head crane and the space beneath the jib and on both sides of it. Alternatively, as shown in Figure 2, this envelope may be composed of different parallelopiped sections; viz a portion 32 which surrounds the undercarriage 17, the superstructure 16 and part of the jib 19, a portion 33 which surrounds the major part of the jib 19 between the envelope portions 32 and 33. When the jib 19 is swung laterally, the envelope 31 in Figure 1 deforms accordingly and the portions 33 and 34 of the envelope shown in Figure 2 partake of the swinging movement.

The computer 23 follows the movements of the envelopes corresponding to the movements of the cranes, the jibs of the rotary

cranes and the hammer head crane and, in the case of the envelope shown in Figure 2, the crab of the hammer head crane and a signal is given by the computer 23 when two envelopes approach each other to a given minimum spacing. This signal is sent by a transmitter 35 (Figure 6) to receivers 36 on the cranes concerned.

The transmission of data from the transmitters 26 of the cranes to the receiver 24 of the computer and from the transmitter 35 of the computer to the receivers 36 of the cranes can be effected in various ways; for example by radio, by conductors or by inductive couplings, e.g. induction loops. The impulses received by the receiver 24 are translated into a language intelligible to the computer 23 and fed to the computer. To set up the apparatus the geometrical measurements of the crane tracks and the cranes at the levels to be monitored and data regarding the associated crane driving mechanism and its transmission gearing are programmed into the computer 23. If, later, a crane is added to or subtracted from the installation or a crane is rebuilt, the programme of the computer is changed accordingly.

The computer 23 interrogates the cranes cyclically, tests the data for plausibility and calculates the spacial positions of the cranes in terms of the abovementioned envelopes and so ascertains whether cranes are on a collision course. When this is the case a warning is first sent at a high priority level to the drivers of the cranes concerned. Light indicators 37 in the drivers' cabins can be used for this purpose. These are preferably luminous circuit diagrams with spatial representation of the cranes. In case of danger the crane driver is also shown on the diagram the direction in which the crane may safely be moved out of the danger zone. When the crane driver does not react to a danger signal, e.g. on the luminous circuit diagram, the signals transmitted from the computer and received by the receivers 36 concerned cause the associated crane driving mechanisms to be cut out by respective relays 38.

When a crane is taken out of operation and stopped on its rails, its position is stored in the computer. The storage enables the computer to prevent any other crane from striking the stationary crane.

The data supplied to the receiver 24 of the computer are, as explained above, determined by the operational movements of the crane driving mechanisms concerned. However, a crane or a part thereof may be moved otherwise than by a crane driving mechanism. Thus impact of wind on the jib of a rotary crane may result in rotation of the jib and the crane superstructure which could result in collisions with other cranes. The pick ups 27 measure movements of the crane or crane part in response to operation of its driving mechanism. To enable account to be taken of movement of a crane part due to wind when its driving mechanism is not in operation, the cranes are provided with batteries which enable the pick ups 27 to supply data to the computer 23 in response to such movements.

The transmitters 26 of the cranes can in the case of transmission of digital data be impulse senders and include a rotary disc with one or more holes through which a light beam impinges on a photocell. Alternatively a rotating toothed disc can be used, with its teeth influencing an electrical field.

Figures 3 to 6 show the case in which a gantry crane 39 is entirely enclosed by an imaginary parallelopiped envelope 40, which is formed by the computer 23. It is also assumed that a rotary crane 42, on rails between those 43 of the gantry crane, is entirely surrounded, including the jib 44 and the suspended load 45, by an envelope 46 having the form of a right circular cylinder with its axis coincident with the rotational axis 47 of the rotary crane and with a radius r sufficient for it to extend beyond the load 45.

When the rotary crane 41 approaches the gantry crane 39 and the distance between the envelopes 46 and 40 reaches a minimum value A, the computer emits a signal S to warn the driver of the rotary crane and, if the driver does not react, to shut off the driving mechanism of the rotary crane. When the gantry crane approaches the rotary crane the computer supplies the signal to the driver's cabin of the gantry crane. The drivers of both cranes receive warning signals when both cranes move. The computer 23 receives data corresponding to the movements of the driving mechanism and luffing gear of the rotary crane and other data corresponding to the movements of the driving mechanism of the gantry crane. Figures 5 and 6 show the case when the jib 44 of the rotary crane is luffed down. The radius R of the cylindrical envelope 48 then increases and its height diminishes. The greater the relative speed at which the two cranes approach each other the greater must be the minimum distance A.

While in the instance shown in Figures 3 to 6, the rotary crane can only approach the gantry crane to a given limit but may not pass through it, Figures 7 and 8 provide for a rotary crane 49 to be allowed to pass through a gantry crane 50 under certain conditions. To this end the computer forms an envelope 51 which leaves free part of the opening in the gantry of the gantry crane. It consists of a parallelopiped portion 52 which surrounds the girder, two parallelopiped portions 53, 54 which surround the supports of the girder and a parallelopiped portion 55 which surrounds a crab 56 and a load 57 suspended from it, the latter at all levels

because the envelope portion 55 extends almost to the ground. The rotary crane 49 including the load 59 suspended from its jib 58 is surrounded by an envelope 60, the dimensions of which vary in accordance with the extent of luffing of the jib 58 and in dependance on the angular position of the rotatable superstructure with respect to the vertical axis 61. Only when the envelope 60 has dimensions such that it cannot contact the portions 52, 54, 55 of the envelope 51 surrounding the gantry crane will the computer permit the rotary crane 49 to pass through the gantry crane 50. When these conditions are not fulfilled, it emits a signal S to warn the crane driver or drivers or to stop the crane driving mechanism concerned. To this end data are supplied to the computer 23 which correspond to the movements of the chassis, the luffing mechanism and the rotational mechanism of the rotary crane 49 and also data which correspond to the movements of the chassis of the gantry crane 50 and its crab driving mechanism.

Figures 9 to 15 relate to a crane assembly for a shipyard which includes two gantry cranes 62, 63 which run on common rails 64, between and parallel to which are two rail tracks 65, 66. Two hammer head cranes 67, 68 run on the track 65 and a hammer head crane 69 runs on the track 66. The height of the hammer head cranes is such as to enable them to pass beneath the girders 70 of the gantry cranes 62, 63 when their jibs are suitably positioned. Outside and parallel to the track formed by the rails 64 is a rail track 71 on which runs a larger hammer head crane 72 which can pass the gantry cranes 62, 63 when its jib is suitably positioned.

The computer is programmed in this case on the basis that the hammer head cranes 67, 68 and 69 cannot approach each other to such an extent that the circles 73, 74, 75 described by the tips of their jibs as they rotate touch. Consequently these are centre distances in the direction of travel which must for safety reasons be greater than those indicated at a, b and c in Figure 10. These distances, which depend on the radii R_1, R_2, R_3 of the three circles, are as follows:—

$$a=R_1+R_2$$
$$b=(R_1+R_3)\sin\alpha$$
$$c=(R_2+R_3)\sin\beta$$

The angles α and β are those between the vertical planes through the centres of the pairs of cranes 67, 69 and 68, 69 respectively and the planes through the centres of the cranes perpendicular to the direction of travel. In corresponding fashion the minimum distance in the direction of travel between the hammer head cranes 72 and 79 is the sum of the distance d and an added minimum amount.

The distance d is calculated as follows:—

$$d=(R_3+R_4)\sin\gamma$$

where γ is the angle between the plane through the centres of the cranes 69, 72 and the planes through the centres of these cranes perpendicular to the direction of travel and R_4 is the radius of the jib circle of the crane 72. The angles α, β, γ are given by the equations:—

$$\cos\alpha=S:(R_1+R_3)$$
$$\cos\beta=S:(R_2+R_3)$$
$$\cos\gamma=S_1:(R_3+R_4)$$

where S is the distance between the centres of the tracks 65, 68 and S_1 is the distance between the centres of the tracks 66 and 71.

Figures 11 and 12 show the conditions for passage of the hammer head crane 68 through the gantry crane 62. The jib of the hammer head crane must be swung so that its tip can pass the column 76 of the gantry crane 62 with clearance. For this to be so the tip of the jib must have a maximum distance e (Figure 12) from the centre of the track 65 given by:—

$$e=S_2-\text{“u”}-k$$

where S_2 is the distance between the centre of the nearer rail 64 and the centre of the track 65, "u" is the distance by which the inside of the support 76 projects from the centre of the rail 64 towards the track 65 and k is a safety factor. The maximum distance e corresponds to an angle δ between the vertical longitudinal plane of the jib and the plane through the axis of rotation of the crane 68 perpendicular to the direction of travel. The angle δ is included in the programme of the computer.

In addition, passage of the hammer head crane 68 through the gantry crane 62 is only permissible when it will not collide with a load suspended from the crab 77 of the gantry crane. As shown in Figures 11 and 12, the computer forms an envelope 79 surrounding the load at all levels and in parallelopiped form. The crab 77 may only approach the pillar 76 to an extent such that the rearward part of the jib of the hammer head crane 68 when set to the angle of swivel δ can pass the envelope 79. The corresponding distance between the centre of crab 77 and the fixed support 76 is indicated at f in Figures 11 and 12.

Figure 13 shows how closely the hammer head crane 68 can approach the gantry crane 62 without its jib colliding with the support 76 or the load 78 suspended from the crab 77. For this to be possible the pivotal centre

of the hammer head crane must be spaced at least by distance g from the vertical longitudinal plane 80 of the gantry crane. This is given by:—

$$g=h+\tfrac{1}{2}t$$

where

$$\frac{e}{\tan \delta}$$

and t is the width of the girder 70.

Under this condition the tip of the jib passes the edge of the support 76 with clearance. The crab 77 may not travel towards the support 76 sufficiently for the circle described by the tip of the jib to touch the envelope 79. Accordingly the centre of the crab 77 must be spaced from the support 76 by at least the distance i shown in Figures 11 and 13.

Figures 14 and 15 show the angular position which the jib of the hammer head crane must assume for it to be able to pass without danger through the gantry crane 62. To permit this, the maximum distance of the tip of the jib from the centre of the track 71 must be:—

$$m=S_3-\text{“u”}-k$$

where S_3 is the distance between the nearer rail 64 and the centre of the track 71. This corresponds to an angle ε between the longitudinal central plane of the jib and the plane through the centre of the jib perpendicular to the direction of travel.

To enable the jib of the hammer head crane 72 to be rotated without limitation and without colliding with the gantry crane, the centre of the hammer head crane must be spaced from the vertical central longitudinal plane 80 of the gantry crane at least by a distance n, given by:

$$n=o+\tfrac{1}{2}t$$

where $o=m \tan\varepsilon$.

WHAT WE CLAIM IS:—

1. A crane assembly comprising at least two cranes mounted to travel on rails so that they can pass each other or so that one crane can pass under another, transmitters on the cranes for emitting data representing the instantaneous positions of the cranes and of parts of the cranes and/or of loads carried by the cranes which are subject to danger of collision upon approach of the cranes towards one another, and a computer having a receiver for receiving the transmitted data, the computer being programmed to form imaginary envelopes from the received data which surround crane parts and/or loads subject to danger of collision and emitting a warning signal when two envelopes become dangerously close to one another.

2. An assembly according to Claim 1, in which the envelopes are right prisms or cylinders which extend from the highest endangered portions of the cranes approximately to ground level.

3. An assembly according to Claim 1 or Claim 2, which includes a rotary crane and a gantry crane and in which the computer emits a warning signal when the rotary crane seeks to move through or past the gantry crane when the angle between the vertical longitudinal plane through the jib of the rotary crane and a plane parallel to the vertical central longitudinal plane of the gantry crane exceeds a minimum value and when the distances between a crab of the gantry crane from the supports of its girder exceed determined minimum values.

4. An assembly according to Claim 3, in which the rotary crane has a luffing jib and in which the computer emits a warning signal, upon approach of the rotary crane to the gantry crane, unless the tip of the jib is disposed below the girder of the gantry crane.

5. An assembly according to any one of the preceding Claims, which includes receivers in crane driver's cabins of the cranes which receive the warning signals from a transmitter in the computer.

6. An assembly according to Claim 5, in which the drivers' cabins contain luminous circuit diagrams which indicate in response to the signals received by the receivers in the cabins dangerous positions of the cranes or crane parts.

7. An assembly according to Claim 6, in which the luminous circuit diagrams also afford indications of the direction in which the cranes or crane parts can be moved out of the danger zone.

8. An assembly according to any one of the preceding Claims in which the computer stores data from stationary cranes.

9. An assembly according to any one of the preceding Claims, which includes batteries on the cranes to provide for the supply to the computer of data representing movements of cranes or crane parts arising from influences (e.g. wind) other than the crane driving mechanisms.

10. An assembly according to any one of the preceding Claims, which includes means for automatically stopping the crane driving mechanisms in the event of warning signals being ignored by a crane driver.

11. A crane assembly according to Claim 1, substantially as described herein with reference to Figures 1 and 2 of the accompanying drawings.

12. A crane assembly according to Claim 1, substantially as described herein with

reference to Figures 3—6 of the accompanying drawings.

13. A crane assembly according to Claim 1, substantially as described herein with reference to Figures 7 and 8 of the accompanying drawings.

14. A crane assembly according to Claim 1, substantially as described herein with reference to Figures 9—15 of the accompanying drawings.

BREWER & SON,
Chartered Patent Agents,
5—9 Quality Court,
Chancery Lane,
London WC2A 1HT.

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FIG. 1

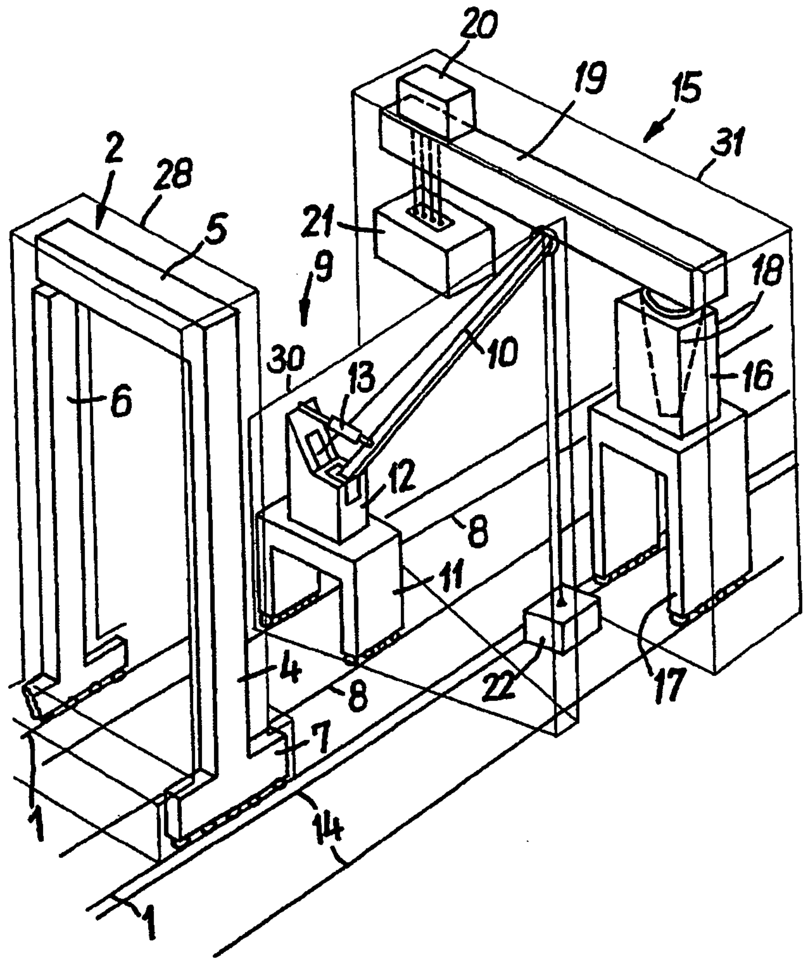


FIG. 2

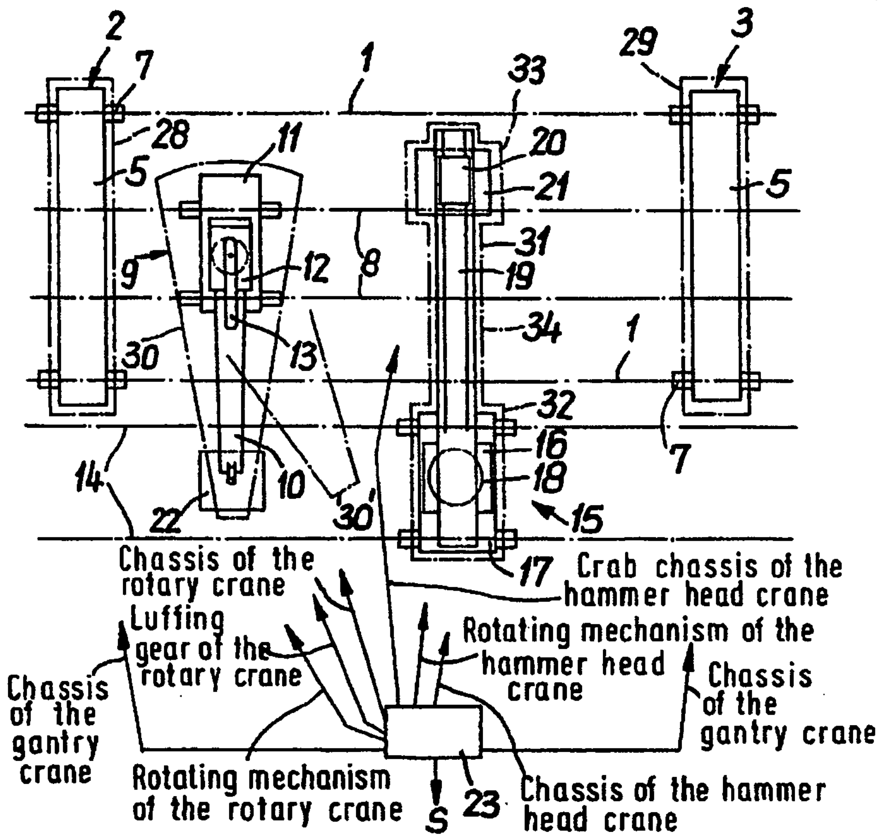

2
3
29
7
1
33
20
21
28
11
5
5
31
9
12
8
19
34
30
13
1
32
16
7
14
10
18
22
30'
15
17
Chassis of the rotary crane
Crab chassis of the hammer head crane
Luffing gear of the rotary crane
Rotating mechanism of the hammer head crane
Chassis of the gantry crane
Chassis of the gantry crane
Rotating mechanism of the rotary crane
S
23
Chassis of the hammer head crane

FIG. 3

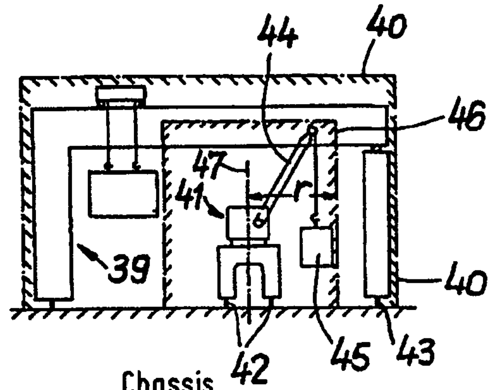


FIG. 4

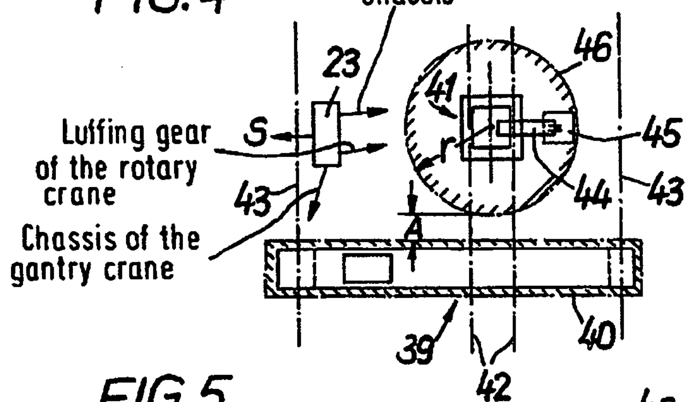
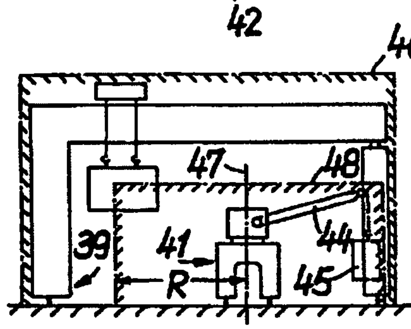


FIG. 5



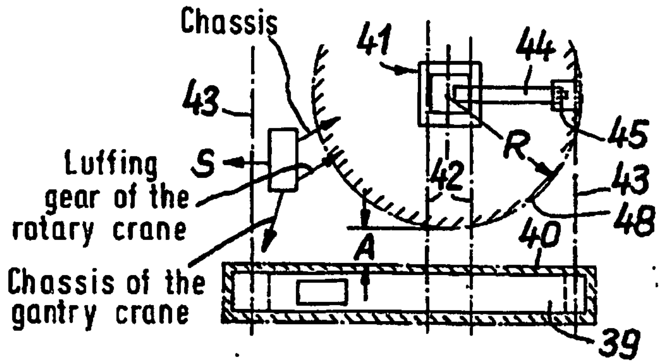


FIG. 6

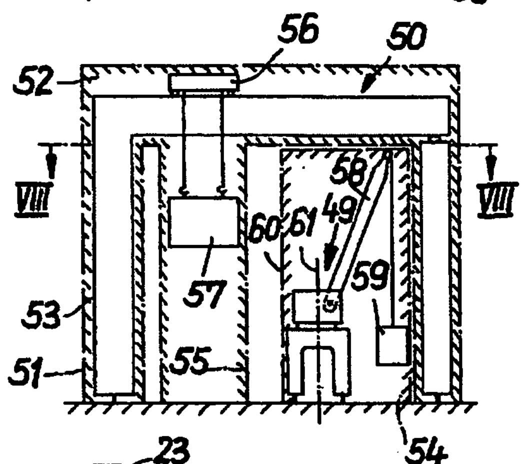


FIG. 7

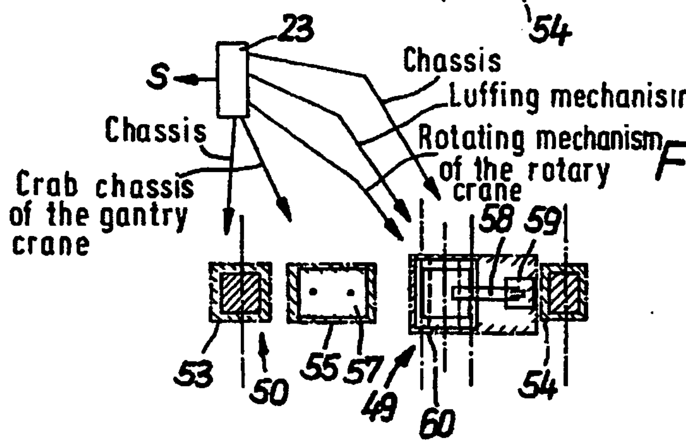


FIG. 8

FIG. 9

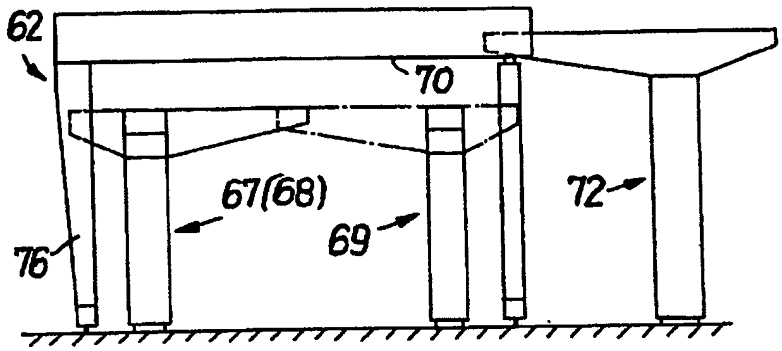

62
70
67(68)
72
69
76

FIG. 11

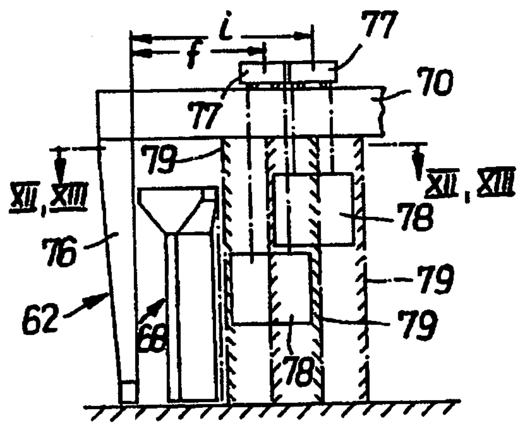
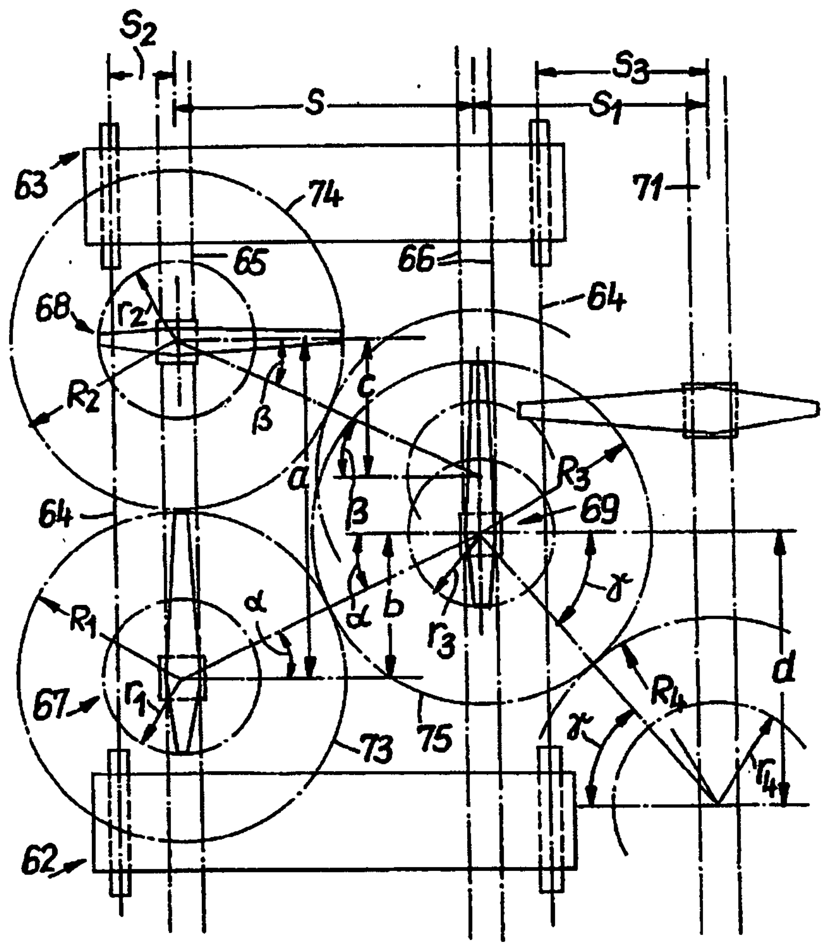

l
f
77
77
70
79
XII, XIII
XII, XIII
78
76
79
62
68
79
78

FIG. 10


S2
S
S3
S1
63
74
71
65
66
64
68
r2
R2
β
c
a
β
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γ
r4
62

FIG. 12

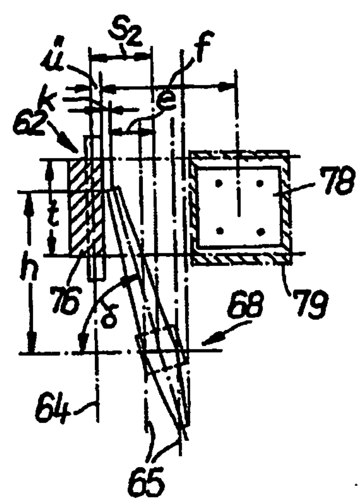

FIG. 13

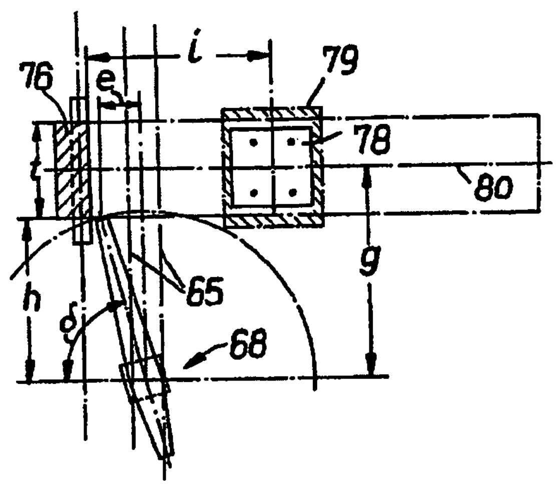

FIG. 14

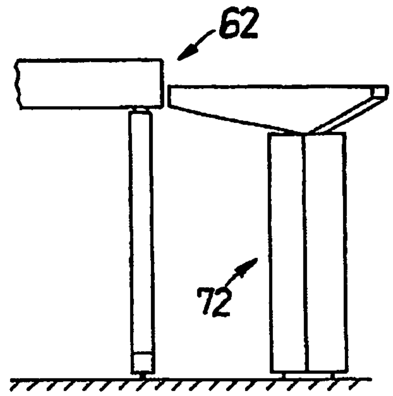

FIG. 15

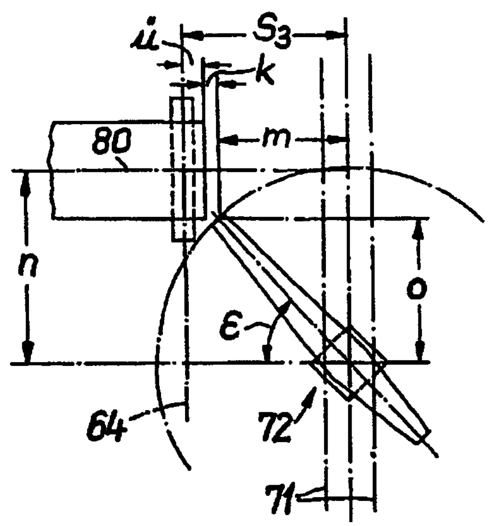

FIG. 16